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HORIZONTAL AND VERTICAL INTEGRATION OF RICE MARKETS IN JAMBI PROVINCE

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Abstract

Variations in rice-price movements across regions and marketing levels indicate that price formation and market-information transmission are not uniform. This study describes rice-price developments at the producer level in Jambi, West Sumatra, and South Sumatra and at the wholesale and consumer levels in Jambi, and analyses horizontal and vertical market integration. Monthly prices from January 2021 to April 2026 were examined using descriptive and linear-trend analysis, vector autoregression, and error correction models within a cointegration framework. All series trended upward, although their rates of change and fluctuations differed. Producer markets did not share a long-run equilibrium, but one-way short-run linkages ran from West Sumatra to Jambi and from Jambi to South Sumatra. Vertically, the South Sumatra chain exhibited the broadest set of long-run relationships, whereas the West Sumatra and local Jambi chains showed no long-run linkage between producer and downstream prices. The wholesale-consumer segment displayed the most consistent adjustment mechanism. Rice-market integration in Jambi therefore varies across regions, marketing levels, and time horizons and does not necessarily imply proportional price transmission. The study's originality lies in jointly analysing price trends and horizontal and vertical integration while retaining the geographical identity of each producer-price series.

Keywords: horizontal integration; price transmission; price trends; rice prices; vertical integration

INTRODUCTION

Rice occupies a strategic position in Indonesia's food economy because changes in its price affect household purchasing power, production incentives, marketing margins, and food-price stability. In Jambi Province, prices are formed within a distribution network involving local production, interregional supplies, wholesalers, retailers, and consumers. Statistics Indonesia (2025) shows that rice distribution may involve several marketing agents, while Ruspayandi et al. (2022) emphasise that price stabilisation requires coordination among market mechanisms, stock management, and government policy.

Empirical evidence on rice-price linkages remains mixed. Aryani et al. (2021) found that Indonesia's rice markets were not fully integrated, whereas Shaffitri et al. (2024) identified both short-run and long-run relationships across several marketing levels. Asrin et al. (2022) showed that the producer–consumer price relationship may be disrupted during particular periods. In a broader context, Nguyen et al. (2025) and Zahra et al. (2026) demonstrated that product quality, crisis conditions, and seasonality can alter the strength and direction of price transmission.

The research gap lies in the limited evidence that simultaneously examines horizontal linkages among producer markets and compares vertical relationships according to the geographical origin of producer-price series facing a common downstream market. The use of an aggregate producer price may conceal differences in price relationships among Jambi, West Sumatra, and South Sumatra. This study therefore retains the identity of each price series so that heterogeneity in intermarket relationships can be identified.

The analysis reports integration by market pair, marketing level, and time horizon. Granger causality is interpreted as predictive content rather than evidence of structural causality or the physical direction of rice trade. Accordingly, the study aims to: (1) describe rice-price developments at the producer level in Jambi, West Sumatra, and South Sumatra and at the wholesale and consumer levels in Jambi Province; and (2) analyse the existence and pattern of horizontal integration among producer markets and vertical integration in the West Sumatra, South Sumatra, and local Jambi chains.

LITERATURE REVIEW

Prices

In an agribusiness system, prices provide signals for production, storage, distribution, and consumption decisions. Price differences across regions or marketing levels do not necessarily indicate inefficiency because they may reflect differences in transfer costs, quality, risk, and marketing functions (Graubner et al., 2021; Herawati & Harianto, 2021). Price developments can be summarised by a time trend that indicates the direction and average rate of change over the observation period; however, a trend coefficient neither identifies the causes of change nor establishes intermarket linkages (Wooldridge, 2020).

Market Integration

Market integration refers to a systematic relationship between prices in different markets. Horizontal integration links markets at the same marketing level across locations, whereas vertical integration links prices at the producer, wholesale, and consumer levels. Ravallion (1986) and Fackler and Goodwin (2001) explain that markets may be integrated even when nominal prices differ, provided that the differences are consistent with transfer costs. Cointegration indicates a long-run equilibrium relationship but does not, by itself, establish perfect competition, market efficiency, or proportional price transmission (von Cramon-Taubadel & Goodwin, 2021).

Price Transmission

Price transmission describes the direction, magnitude, and speed with which a price at one marketing level responds to a price change at another level. Vavra and Goodwin (2005) identify adjustment costs, inventories, and distribution functions as sources of delayed price pass-through. An elasticity below one indicates a less-than-proportional response, although its interpretation must account for market structure and marketing costs. Deb et al. (2020), Arida et al. (2023), and Emediegwu and Rogna (2024) show that agricultural price transmission may differ between the short run and the long run and need not be symmetric.

Rice

Rice is a strategic food commodity with important production, distribution, consumption, and price-policy dimensions. Differences in product quality and form limit the comparability of price series, while the length and structure of marketing channels affect costs and the share of the final price received by each market participant. Prihtanti and Pangestika (2020) document a relationship between procurement-price policy and retail-price developments, whereas Oksalia et al. (2023), Wahyuni et al. (2023), and Nasir et al. (2025) show that the structure of rice-marketing channels and the functions performed by marketing institutions generate different margins. Statistics Indonesia (2025) also highlights the important role of wholesalers in distributing rice from producers to final consumers.

METHOD

Data, Variables, and Analytical Design

This study employs a quantitative time-series econometric approach. The data comprise 64 monthly rice-price observations from January 2021 to April 2026, obtained from Bank Indonesia’s National Strategic Food Price Information Center (PIHPS). Each observation is the monthly average price for producer markets in Jambi, West Sumatra, and South Sumatra and for the wholesale and consumer markets in Jambi Province. All prices are expressed in Indonesian rupiah per kilogram and transformed into natural logarithms. The logarithmic transformation standardises the scale of the variables and allows coefficients in log-linear models to be interpreted as elasticities (Wooldridge, 2020).

Table 1. Operational Definitions of the Research Variables

Variable	Definition	Unit	Logarithmic Notation
Pf Jambi	Rice price in the producer market of Jambi Province	IDR/kg	LPf Jambi
Pf Sumbar	Rice price in the producer market of West Sumatra Province	IDR/kg	LPf Sumbar
Pf Sumsel	Rice price in the producer market of South Sumatra Province	IDR/kg	LPf Sumsel
Pw Jambi	Rice price in the wholesale market of Jambi Province	IDR/kg	LPw Jambi
Pc Jambi	Rice price in the consumer market of Jambi Province	IDR/kg	LPc Jambi

Note: Pf denotes the producer price; Pw denotes the wholesale price; and Pc denotes the consumer price

As shown in Table 1, the term producer price follows the PIHPS market-type classification. *Pf* therefore does not necessarily equal farmers' net receipts after quality discounts, transport costs, and transaction costs. This definitional limitation follows the commodity-comparability principle in spatial price analysis: interpretations apply only to the price category that is actually observed (Fackler & Goodwin, 2001).

Horizontal integration is modelled as a system comprising the three producer-price series. Vertical integration is examined for the *Pf Sumbar–Pw Jambi–Pc Jambi*, *Pf Sumsel–Pw Jambi–Pc Jambi*, and *Pf Jambi–Pw Jambi–Pc Jambi* chains. The *Pw Jambi–Pc Jambi* relationship is the common downstream segment in all three chains. Following the vertical-transmission framework of von Cramon-Taubadel and Goodwin (2021), the *Pf–Pc* relationship measures overall price transmission from producer to consumer after the functions of assembly, processing, storage, transport, wholesaling, and retailing have taken place; it does not represent a direct physical transaction between producers and consumers.

Price Development Analysis

Price developments are examined descriptively using monthly line graphs and linear-trend models. The graphs identify the direction of movement, changes across periods, and differences in price patterns across regions and marketing levels. Trend analysis complements the graphical evidence by estimating the average monthly change over the observation period. Wooldridge (2020) explains that a time trend summarises systematic change over time but does not identify its underlying causes. The linear-trend model is specified as follows:

$$Y_t = a + bt + e_t \quad (1)$$

In Equation (1), Y_t is the rice price in month t, a is the estimated intercept, b is the average monthly price change, t is the time index, and e_t is the error term. A positive b indicates an upward price trend, whereas a negative coefficient indicates a downward trend. The trend coefficient measures the average nominal change and does not establish causality or an intermarket price relationship.

Horizontal Market Integration Analysis

The horizontal analysis begins with the Augmented Dickey–Fuller (ADF) unit-root test to determine the order of integration. A series that is non-stationary in levels but stationary in first differences is classified as integrated of order one, I(1). The lag order is selected using the sequential modified likelihood-ratio (LR) test, final prediction error (FPE), Akaike information criterion (AIC), Schwarz information criterion (SC), and Hannan–Quinn information criterion (HQ). Following Lütkepohl (2005), the selected lag order is subsequently assessed through model-stability and residual-autocorrelation tests to avoid misspecification of the dynamic system.

Long-run relationships are then tested using the Johansen procedure based on the trace and maximum-eigenvalue statistics. When the cointegration rank is greater than zero, the system can be represented by a vector error correction model (VECM); when the rank is zero, short-run dynamics are estimated using a vector autoregression (VAR) in first differences. The general VAR specification is given in Equation (2).

$$\Delta P_t = c + \Sigma_{i=1}{}^{p} A_i \Delta P_{t-i} + \varepsilon_t \quad (2)$$

In Equation (2), ΔP_t is the vector of changes in the logarithms of producer prices in Jambi, West Sumatra, and South Sumatra; A_i is a matrix of lag coefficients; c is a vector of constants; and ε_t is a vector of disturbances. Cross-variable coefficients capture dynamic intermarket relationships after controlling for lagged prices in the system, whereas own-lag coefficients capture persistence or internal correction. Stability is assessed using the roots of the characteristic polynomial, and residual autocorrelation is examined using the VAR Residual Serial Correlation LM Test (Hamilton, 1994; Lütkepohl, 2005).

The direction of short-run predictive linkages is examined using the VAR Granger Causality/Block Exogeneity Wald Test. The null hypothesis is that all lagged coefficients of a given variable are jointly equal to zero in another price equation. Granger (1969) emphasises that rejection of the null indicates additional predictive content, not structural causality. The results are therefore not interpreted as evidence of the physical direction of trade.

Vertical Market Integration Analysis

Vertical integration is tested bilaterally using the Engle–Granger approach because each hypothesis concerns a *Pf–Pw*, *Pw–Pc*, or *Pf–Pc* relationship. The first stage estimates a long-run equation in levels and obtains the equilibrium residual. The long-run relationship is specified in Equation (3).

$$ln(P_{\gamma,t}) = \alpha + \beta ln(P_{x,t}) + u_t \tag{3}$$

In Equation (3), P_x is the upstream price, P_γ is the downstream price, β is the long-run transmission elasticity, and u_t is the equilibrium residual. Engle and Granger (1987) show that two I(1) series are cointegrated when the residual from the levels equation is stationary. This study uses the probabilities of the tau and z statistics. Cointegration is identified at the 5% significance level when both statistics reject the null hypothesis of no cointegration; when only one statistic is significant, the result is classified as indicative evidence of cointegration and interpreted cautiously.

For cointegrated price pairs, short-run responses and the adjustment towards long-run equilibrium are estimated using an error correction model (ECM). Dummy variables are included for the pronounced price changes in October 2022 and March 2024 so that these observations do not dominate the estimates; the dummies do not assign an economic cause to those movements. The general ECM specification is given in Equation (4).

$$\Delta ln(P_{\gamma,t}) = \gamma_0 + \gamma_1 \Delta ln(P_{x,t}) + \lambda ECT_{t-1} + \Sigma_j \delta_j D_{j,t} + \nu_t \tag{4}$$

In Equation (4), γ_1 is the short-run transmission elasticity, λ is the error-correction coefficient, D_j denotes a dummy variable for a pronounced price movement in a particular period, and ν_t is the disturbance term. A negative and statistically significant λ indicates that the dependent price corrects part of the previous period's deviation from long-run equilibrium. An insignificant error correction term (ECT) does not invalidate the first-stage cointegration result; rather, it indicates that the dependent variable in that equation is not shown to adjust to the disequilibrium. Establishing weak exogeneity would require a more complete system-based test (Engle & Granger, 1987; von Cramon-Taubadel & Goodwin, 2021).

ECM adequacy is evaluated using the Breusch–Godfrey LM, Breusch–Pagan–Godfrey, Jarque–Bera, and Ramsey RESET tests. A Wald test of H_0: $\beta = 1$ distinguishes the existence of a long-run relationship from proportional transmission. Vavra and Goodwin (2005) note that an elasticity below one indicates less-than-proportional transmission, but is insufficient to establish market efficiency without information on costs, margins, and market structure.

RESULTS AND DISCUSSION

Rice Price Developments in Jambi Province

Producer Level Rice Price Developments by Region

Figure 1 shows that producer rice prices in Jambi, West Sumatra, and South Sumatra generally increased between January 2021 and April 2026, although their levels and fluctuations differed. West Sumatra's producer price remained relatively higher for most of the observation period. South Sumatra displayed the sharpest fluctuations, whereas Jambi's producer price rose more markedly from 2023 onwards. These differences are consistent with spatial-price theory, which identifies transfer costs, product quality, supply conditions, and marketing networks as factors that may sustain regional price differentials (Fackler & Goodwin, 2001). Nguyen et al. (2025) likewise show that rice quality and changing market conditions can generate heterogeneous regional price responses.

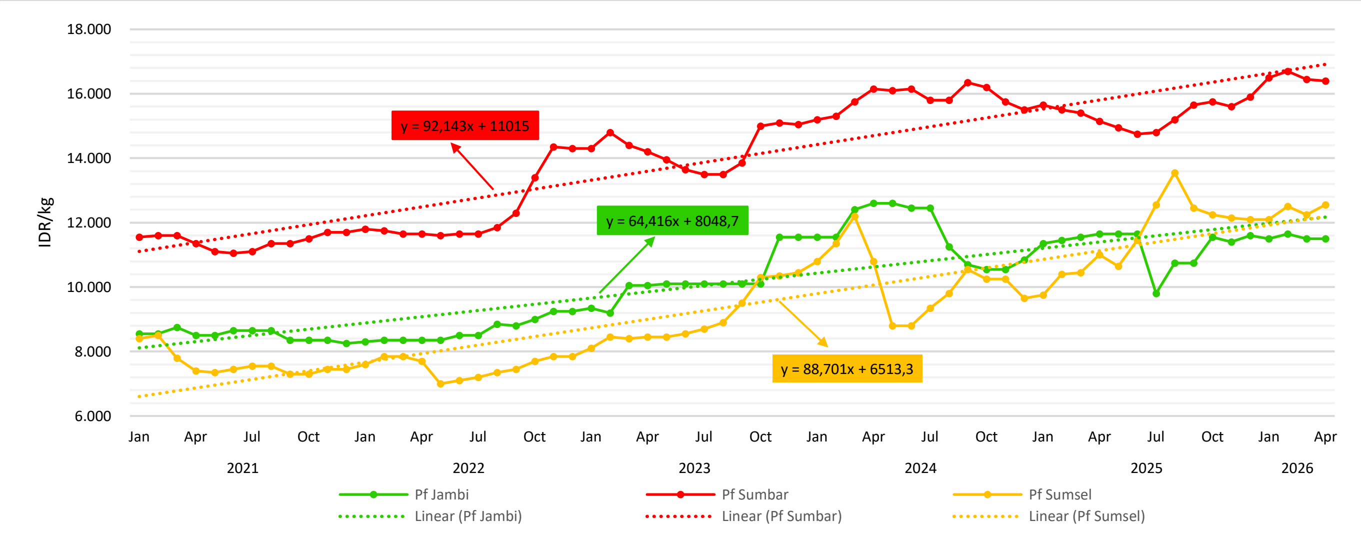

Figure 1. Producer-Level Rice Prices in Jambi, West Sumatra, and South Sumatra, January 2021–April 2026
Source: National Strategic Food Price Information Center (PIHPS), 2026
Note: Pf denotes the producer price

The trend equations in Figure 1 have positive coefficients for all three producer-price series. West Sumatra's coefficient of 92.143 indicates an average nominal increase of approximately IDR 92.14/kg per month; the corresponding increases for South Sumatra and Jambi are approximately IDR 88.70/kg and IDR 64.42/kg per month. These coefficients summarise average movements over the observation period and do not imply that prices rose by the same amount every month. Wooldridge (2020) explains that a time-trend coefficient captures systematic change but does not identify its causes. Prihtanti and Pangestika (2020) relate rice-price developments to production dynamics and price policy, while Onumah et al. (2022) show that rice-price volatility may differ across markets because adjustment processes are heterogeneous.

Differences in trend coefficients alone cannot establish producer-market integration. Prices may rise simultaneously because of inflation, higher production costs, or common shocks without exhibiting a stable adjustment relationship. Rahmadina et al. (2024) demonstrate that rice-market integration must be established through short-run and long-run relationships, while Hoffmann et al. (2026) show that domestic policies and market conditions may limit the transmission of price changes across markets.

Rice Price Developments across Marketing Levels

Figure 2 presents producer prices in Jambi, West Sumatra, and South Sumatra together with wholesale and consumer prices in Jambi. All series trend upward, but producer prices fluctuate more strongly, whereas wholesale and consumer prices adjust more gradually. This pattern indicates that upstream price changes are not necessarily followed by downstream prices at the same time or by the same magnitude. Vavra and Goodwin (2005) explain that inventories, purchasing schedules, distribution functions, and adjustment costs can delay price transmission; Shaffitri et al. (2024) likewise identify differences between short-run and long-run relationships among producer, wholesale, and consumer rice prices.

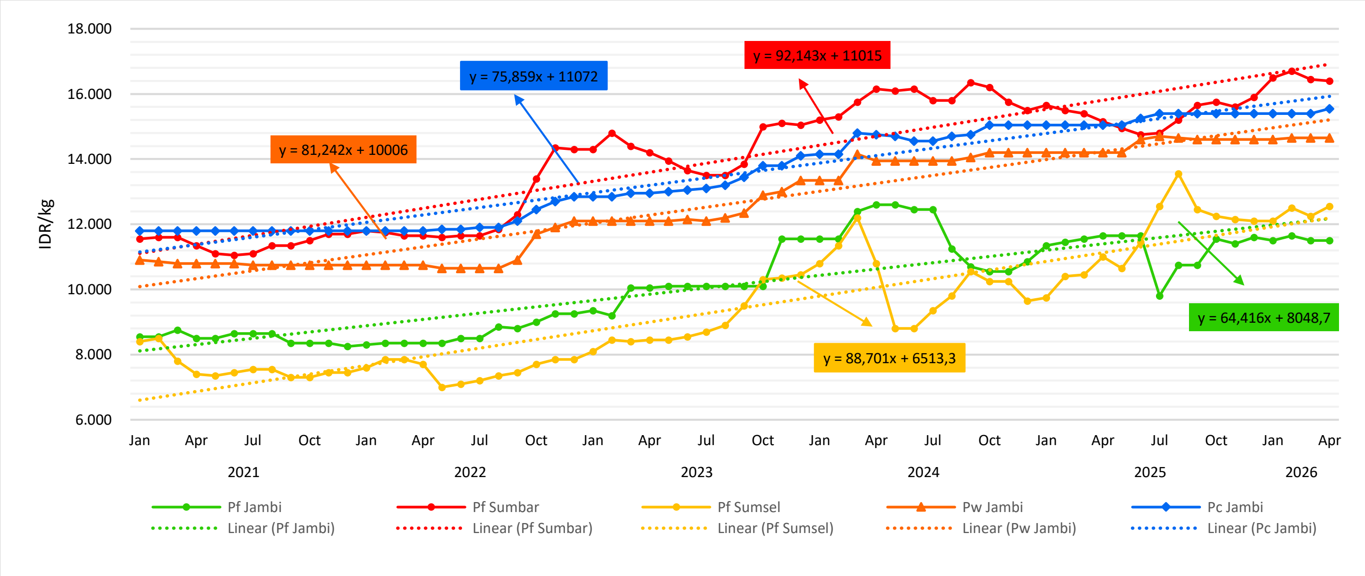

Figure 2. Rice Prices at the Producer, Wholesale, and Consumer Levels in Jambi, West Sumatra, and South Sumatra, January 2021–April 2026

Source: National Strategic Food Price Information Center (PIHPS), 2026

Note: Pf denotes the producer price; Pw denotes the wholesale price; and Pc denotes the consumer price

The trend equations in Figure 2 indicate that Jambi's wholesale and consumer prices increased by an average of approximately IDR 81.24/kg and IDR 75.86/kg per month, respectively. The slightly larger average increase in the wholesale price cannot be interpreted directly as a change in traders' profits because the price spread also includes handling, storage, physical loss, distribution, and business-risk costs. Herawati and Harianto (2021) emphasise that changes in food-price spreads must be interpreted alongside changes in marketing costs and structure. Wahyuni et al. (2023) similarly show that rice-marketing channels generate different costs and margins according to the functions performed by marketing agents.

Although all five trend coefficients are positive, their magnitudes differ. This pattern provides preliminary evidence that price formation varies by region and marketing level. A common trend direction does not establish that a change in one price is transmitted to another or that the price spread returns to a stable equilibrium. Ravallion (1986) and Fackler and Goodwin (2001) define integration as a systematic relationship among markets after transfer costs are considered, while Emediegwu and Rogna (2024) show that agricultural price transmission may be incomplete and heterogeneous across marketing levels.

Horizontal and Vertical Integration of Rice Markets in Jambi Province

Stationarity of the Rice-Price Variables

The ADF tests show that all price series are non-stationary in levels but stationary in first differences. As reported in Table 2, the first-difference probabilities are below 0.01 for all variables; the five series are therefore integrated of order one, I(1). Engle and Granger (1987) and Johansen (1988) establish a common order of integration as a prerequisite for testing long-run equilibrium relationships. This result does not itself demonstrate integration; it determines the appropriate subsequent model and avoids inference from spurious regressions.

Table 2. ADF Unit-Root Test Results for the Rice-Price Variables

Variable	ADF Statistic	p-Value	Lag Order	Decision
D(LPf Jambi)	-8,800323	0,0000	0	Stationary
D(LPf Sumbar)	-4,833271	0,0002	0	Stationary
D(LPf Sumsel)	-6,286650	0,0000	1	Stationary
D(LPw Jambi)	-6,455548	0,0000	0	Stationary
D(LPc Jambi)	-6,375556	0,0000	0	Stationary

Source: Data Processed, 2026

Note: Pf denotes the producer price; Pw denotes the wholesale price; and Pc denotes the consumer price

Lag Order Selection and Model Eligibility

The FPE, SC, and HQ criteria select two lags, whereas the LR and AIC criteria indicate longer lag orders. Given the number of observations and the support of the majority of criteria, two lags are used in the first-difference VAR. For the Johansen test, the levels system uses three lags after the stability and diagnostic checks indicate that this specification is more appropriate. The difference reflects the distinct requirements of testing long-run relationships and estimating short-run dynamics (Johansen, 1988; Lütkepohl, 2005).

Horizontal Integration of Rice Markets in Jambi Province

Horizontal Cointegration

At the 5% significance level, the Johansen test identifies no cointegrating vector among the producer prices in Jambi, West Sumatra, and South Sumatra (Table 3). Both the trace and maximum-eigenvalue statistics fail to reject the null hypothesis of a zero cointegration rank. In Johansen's (1988) framework, this result indicates that no stationary linear combination binds the three producer prices to a common long-run equilibrium.

Table 3. Johansen Cointegration Test Results for Producer Rice Prices

Test	Hypothesis	Eigenvalue	Statistic	Critical Value 5%	p-Value	Decision
Trace	$r = 0$	0,206450	19,49193	29,79707	0,4580	Does not reject H_0
Trace	$r \leq 1$	0,076140	5,386337	15,49471	0,7665	Does not reject H_0
Trace	$r \leq 2$	0,009064	0,555442	3,841465	0,4561	Does not reject H_0
Max-own	$r = 0$	0,206450	14,10560	21,13162	0,3564	Does not reject H_0
Max-own	$r \leq 1$	0,076140	4,830894	14,26460	0,7630	Does not reject H_0
Max-own	$r \leq 2$	0,009064	0,555442	3,841465	0,4561	Does not reject H_0

Source: Data Processed, 2026

The absence of cointegration does not imply that interregional trade is absent. Under spatial-equilibrium theory, arbitrage links prices when price differentials exceed transfer costs and the commodities compared are sufficiently homogeneous (Fackler & Goodwin, 2001). Nguyen et al. (2025) show that quality differences and market conditions can generate heterogeneous transmission even when trade continues, while Hoffmann et al. (2026) demonstrate that domestic policy can insulate local markets from wider price shocks. Transfer costs, quality, policy, and shifts in supply sources may therefore contribute to the absence of a stable long-run price relationship, although the contribution of each factor cannot be identified without additional data.

This finding is consistent with Aryani et al. (2021), who report that Indonesia's rice markets are not fully integrated, but differs from Rahmadina et al. (2024), who identify cointegration among premium-rice markets within a single province. The contrast accords with Ravallion's (1986) argument that integration results depend on market boundaries, commodity homogeneity, and the trade relationship analysed. Onumah et al. (2022) further show that rice-price volatility and transmission vary across markets, so similar trends need not produce a common long-run equilibrium.

VAR Estimation and Granger Causality/Block Exogeneity

Because the Johansen test yields a zero cointegration rank, a VECM is not estimated; short-run relationships are instead modelled using a VAR(2) in first differences. Table 4 reports the three simultaneous equations, allowing cross-market effects to be distinguished from each market's own price dynamics.

Table 4. VAR(2) Estimates for Changes in Producer Rice Prices in Jambi, West Sumatra, and South Sumatra

Variable	ΔLPf Jambi	ΔLPf Sumbar	ΔLPf Sumsel
ΔLPf Jambi(-1)	-0,117777	-0,010784	-0,337829**
	[-0,88812]	[-0,14415]	[-2,16160]
ΔLPf Jambi(-2)	0,131990	0,041595	0,133784
	[1,01479]	[0,56692]	[0,87279]

Variable	ΔLPf Jambi	ΔLPf Sumbar	ΔLPf Sumsel
ΔLPf Sumbar(-1)	0,658004***	0,491251***	-0,381187
	[2,69090]	[3,56137]	[-1,32274]
ΔLPf Sumbar(-2)	-0,171975	-0,212500	0,199342
	[-0,65660]	[-1,43825]	[0,64580]
ΔLPf Sumsel(-1)	-0,101711	0,051614	0,409740***
	[-0,92652]	[0,83349]	[3,16712]
ΔLPf Sumsel(-2)	0,162174	0,039989	-0,259544**
	[1,55359]	[0,67910]	[-2,10976]
Konstanta	0,001207	0,003420	0,008974
	[0,23367]	[1,17347]	[1,47406]
R^2	0,202031	0,258208	0,272848
Adjusted R^2	0,113367	0,175786	0,192053

Source: Data Processed, 2026

Note: The numbers in square brackets are t-statistics; *** indicate significance at the 1%; ** indicate significance at the 5%

Table 4 contains the three equations of the VAR system. Equations (5)–(7) are reported to clarify the direction, lag structure, and sign of each relationship.

$$\Delta LPf\_Jambi_t = 0,001207 - 0,117777\Delta LPf\_Jambi_{t-1} + 0,131990\Delta LPf\_Jambi_{t-2} + 0,658004\Delta LPf\_Sumbar_{t-1} - 0,171975\Delta LPf\_Sumbar_{t-2} - 0,101711\Delta LPf\_Sumsel_{t-1} + 0,162174\Delta LPf\_Sumsel_{t-2} \quad (5)$$

$$\Delta LPf\_Sumbar_t = 0,003420 - 0,010784\Delta LPf\_Jambi_{t-1} + 0,041595\Delta LPf\_Jambi_{t-2} + 0,491251\Delta LPf\_Sumbar_{t-1} - 0,212500\Delta LPf\_Sumbar_{t-2} + 0,051614\Delta LPf\_Sumsel_{t-1} + 0,039989\Delta LPf\_Sumsel_{t-2} \quad (6)$$

$$\Delta LPf\_Sumsel_t = 0,008974 - 0,337829\Delta LPf\_Jambi_{t-1} + 0,133784\Delta LPf\_Jambi_{t-2} - 0,381187\Delta LPf\_Sumbar_{t-1} + 0,199342\Delta LPf\_Sumbar_{t-2} + 0,409740\Delta LPf\_Sumsel_{t-1} - 0,259544\Delta LPf\_Sumsel_{t-2} \quad (7)$$

Equation (5) shows that the first lag of the change in West Sumatra's producer price is positively associated with the current change in Jambi's producer price at the 1% significance level. A 1% increase in West Sumatra's producer price in the previous month is associated with an approximately 0.658% increase in Jambi's producer price in the current month, ceteris paribus. This coefficient represents the dissemination of price information between producer markets and must be interpreted as a predictive relationship rather than structural causality (Granger, 1969). Emediegwu and Rogna (2024) similarly show that agricultural prices may adjust rapidly without transmission being complete or proportional.

Equation (6) shows that the first lag of the change in West Sumatra's producer price is positively associated with its current change at the 1% significance level. A 1% increase in the previous month is associated with an approximately 0.491% increase in the current month. This coefficient indicates persistence: part of the previous period's price movement remains reflected in the following period (Hamilton, 1994). West Sumatra's price dynamics may also be influenced by production, stocks, policy, and linkages with markets outside the system, all of which are components of agricultural price formation (von Cramon-Taubadel & Goodwin, 2021).

Equation (7) indicates that the first lag of the change in Jambi's producer price is negatively associated with the current change in South Sumatra's producer price at the 5% significance level. A 1% increase in Jambi's price in the previous month is associated with a change in South Sumatra's price that is approximately 0.338 percentage points lower. This result represents an opposite short-run response rather than uniform positive transmission. South Sumatra's own first lag is positive and its second lag is negative, indicating an initial continuation followed by correction. Differences in supply timing, harvest seasons, and inventories may also be relevant, but these mechanisms require additional data (von Cramon-Taubadel & Goodwin, 2021; Zahra et al., 2026).

To test whether all lags of a market jointly provide additional predictive information, the VAR estimates are followed by the VAR Granger Causality/Block Exogeneity Wald Test. Table 5 presents the individual and joint tests for each equation. Rejection of the null indicates predictive content, not a structural cause-and-effect relationship or the physical route of trade (Granger, 1969).

Table 5. Granger Causality/Block Exogeneity Wald Test Results for Producer Rice Prices

Relationship Tested	Chi-square	p-Value	Decision
West Sumatra → Jambi	7.622843	0.0221	Granger causality at the 5% level
South Sumatra → Jambi	2.705532	0.2585	No Granger causality
West Sumatra and South Sumatra → Jambi (joint)	11.74730	0.0193	Joint Granger causality at the 5% level
Jambi → West Sumatra	0.388868	0.8233	No Granger causality
South Sumatra → West Sumatra	1.556714	0.4592	No Granger causality
Jambi and South Sumatra → West Sumatra (joint)	1.731700	0.7850	No Granger causality
Jambi → South Sumatra	6.414667	0.0405	Granger causality at the 5% level
West Sumatra → South Sumatra	1.752979	0.4162	No Granger causality
Jambi and West Sumatra → South Sumatra (joint)	8.317413	0.0806	Joint Granger causality at the 10% level

Source: Data Processed, 2026
Note: (joint) refers to a simultaneous test of all lags of the excluded variables

Table 5 shows one-way Granger causality from West Sumatra to Jambi; the reverse direction is not statistically significant. In market-integration terminology, West Sumatra can therefore be interpreted as a short-run price-information reference market and Jambi as a follower market in a predictive sense. Rahmadina et al. (2024) similarly use Granger causality to distinguish reference and follower markets, but Granger (1969) emphasises that these labels do not imply institutional control or the physical flow of the commodity.

The joint tests in Table 5 reinforce this interpretation. The lags of West Sumatra and South Sumatra jointly add predictive content to the Jambi equation at the 5% significance level, with the individual contribution arising primarily from West Sumatra. In the South Sumatra equation, the joint test is significant at the 10% level, while Jambi alone is significant at the 5% level. The joint test in the West Sumatra equation is not significant. Lütkepohl (2005) explains that individual and joint tests impose different restrictions; their different outcomes are therefore not contradictory.

Table 5 also identifies a one-way predictive relationship from Jambi to South Sumatra. Its sign must be read together with Table 4 because Jambi's first-lag coefficient is negative. The sequence West Sumatra → Jambi → South Sumatra therefore describes the short-run flow of predictive information rather than uniform positive price transmission. This difference in response direction, combined with the absence of cointegration, is consistent with the proposition that information may spread more rapidly than arbitrage, which must cover transfer costs and quality differences (Fackler & Goodwin, 2001; Emediegwu & Rogna, 2024).

Vertical Integration of Rice Market in Jambi Province

Vertical Cointegration

Table 6 shows that vertical integration differs according to the geographical origin of the producer-price series. Engle and Granger (1987) define cointegration as a long-run equilibrium relationship between two I(1) series. The results are therefore interpreted for each pair: *Pf–Pw* represents the producer–wholesale relationship, *Pw–Pc* the wholesale–consumer relationship, and *Pf–Pc* overall producer–consumer price transmission along the marketing chain (von Cramon-Taubadel & Goodwin, 2021).

Table 6. Engle–Granger Cointegration Test Results for Vertical Price Relationships

Price Relationship	Dependent Variable	Tau p-Value	Z p-Value	Decision
Pf Sumbar → Pw Jambi	LPw Jambi	0.6431	0.6335	Not cointegrated
Pw Jambi → Pc Jambi	LPc Jambi	0.0595	0.0414	Indicative evidence of cointegration
Pf Sumbar → Pc Jambi	LPc Jambi	0.7215	0.7065	Not cointegrated
Pf Sumsel → Pw Jambi	LPw Jambi	0.0238	0.0101	Cointegrated at the 5% level
Pf Sumsel → Pc Jambi	LPc Jambi	0.0199	0.0108	Cointegrated at the 5% level

Price Relationship	Dependent Variable	Tau p-Value	Z p-Value	Decision
Pf Jambi → Pw Jambi	LPw Jambi	0.1575	0.1149	Not cointegrated
Pf Jambi → Pc Jambi	LPc Jambi	0.2157	0.1582	Not cointegrated

Source: Data Processed, 2026
Note: Pf denotes the producer price; Pw denotes the wholesale price; and Pc denotes the consumer price

For the *Pw Jambi–Pc Jambi* relationship, the tau statistic is significant at the 10% level and the z statistic at the 5% level; the result is therefore classified as indicative evidence of cointegration. This cautious classification follows the Engle–Granger principle that residual stationarity should be interpreted together with the subsequent ECM dynamics. The negative and statistically significant ECT supports the presence of an adjustment mechanism, but does not change the indicative status of the first-stage evidence (Engle & Granger, 1987).

The differences across price pairs in Table 6 confirm that market integration cannot be assigned a single label for an entire chain. Shaffitri et al. (2024) identify vertical integration at the national level, whereas Asrin et al. (2022) report a disruption in the producer–consumer relationship during the pandemic. This heterogeneity is consistent with von Cramon-Taubadel and Goodwin's (2021) argument that transmission depends on product form, marketing level, and policy context.

Vertical Integration in the West Sumatra Chain

The West Sumatra chain is evaluated through the three relationships reported in Table 7. For *Pf Sumbar–Pw Jambi*, the Engle–Granger residual probabilities do not support cointegration. In Fackler and Goodwin's (2001) framework, this finding means that no stable bilateral long-run price relationship is identified; it does not demonstrate that trade is absent. Jambi's wholesale price may be formed from a changing mix of supply origins, quality grades, and marketing costs, although these mechanisms are not causally identified in this study.

The *Pw Jambi–Pc Jambi* segment in Table 7 is common to all three chains. Its positive short-run elasticity and negative, statistically significant ECT indicate that consumer prices respond to wholesale-price changes and correct deviations from the long-run relationship. Deb et al. (2020) show that wholesale prices can lead retail-price formation, while Herawati and Harianto (2021) associate changes in food-marketing margins with the roles of marketing institutions and market transparency.

For *Pf Sumbar–Pc Jambi*, the residual is non-stationary; the levels coefficient is therefore not interpreted as a long-run elasticity. Engle and Granger (1987) warn that regressions between I(1) series with non-stationary residuals may be spurious. Thus, there is no evidence that Jambi's consumer price maintains a stable long-run equilibrium relationship with West Sumatra's producer price, even though West Sumatra serves as a short-run information reference for Jambi's producer market.

Table 7. Vertical Integration in the West Sumatra Chain

Price Relationship	Cointegration	Short-Run Response and ECT	Interpretation
Pf Sumbar → Pw Jambi	Not cointegrated	ECM not estimated	No long-run producer–wholesaler relationship
Pw Jambi → Pc Jambi	Indicative evidence of cointegration	0.582625; ECT -0.197462 and significant at the 1% level	Consumer prices adjust to changes in wholesale prices
Pf Sumbar → Pc Jambi	Not cointegrated	ECM not estimated	No long-run producer–consumer relationship along the chain

Source: Data Processed, 2026
Note: Pf denotes the producer price; Pw denotes the wholesale price; and Pc denotes the consumer price

Overall, Table 7 indicates that the West Sumatra chain is not integrated in the segments linking producers to downstream markets, although the wholesale–consumer segment provides indicative evidence of integration. This result differs from Rahmadina et al. (2024), who find integration among premium-rice retail markets within West Sumatra, because their study concerns a single province and a relatively more homogeneous product. The difference in spatial scale and marketing level is consistent with the proposition that integration depends on market definition and commodity comparability (Ravallion, 1986; Nguyen et al., 2025).

Vertical Integration in the South Sumatra Chain

The cointegration results in Table 6 show that South Sumatra's producer price and Jambi's wholesale price share a long-run equilibrium relationship at the 5% significance level. This relationship is specified in Equation (8). The residual from the long-run equation is used as the error correction term (ECT) in the ECM to estimate short-run adjustment (Engle & Granger, 1987).

$$LPw\_Jambi_t = 3.952586 + 0.600777\ LPf\_Sumsel_t \quad (8)$$

The coefficient of 0.600777 in Equation (8) indicates that a 1% increase in South Sumatra's producer price is associated with an approximately 0.601% increase in Jambi's wholesale price in the long run. The coefficient is below one, and the Wald test rejects H_0: $\beta = 1$; long-run transmission is therefore less than proportional. Vavra and Goodwin (2005) explain that prices at different marketing levels incorporate different functions and costs, while Oksalia et al. (2023) show that buyer structure, market information, and marketing channels affect rice-marketing margins.

The ECM then estimates the response of Jambi's wholesale price to the contemporaneous change in South Sumatra's producer price and its adjustment to the previous period's disequilibrium. Dummy variables control the pronounced price movements in October 2022 and March 2024 so that these observations do not dominate the principal relationship. The estimates are reported in Equation (9) and Table 8.

$$\Delta LPw\_Jambi_t = 0.002396 + 0.072523\Delta LPf\_Sumsel_t - 0.009291ECT_{t-1} + 0.065920D_{2022}M_{10} + 0.049982D_{2024}M_{03} \quad (9)$$

Table 8. ECM Estimates for South Sumatra Producer Prices and Jambi Wholesale Prices

Variable	Coefficient	Standard Error	t Statistic	p-Value	Decision
C	0.002396	0.001094	2.190845	0.0325	Significant at the 5% level
D(LPf Sumsel)	0.072523	0.023084	3.141629	0.0026	Significant at the 1% level
ECT(-1)	-0.009291	0.023532	-0.394842	0.6944	Not significant
Dummy 2022M10	0.065920	0.008609	7.656739	0.0000	Significant at the 1% level
Dummy 2024M03	0.049982	0.008926	5.599566	0.0000	Significant at the 1% level

Source: Data Processed, 2026
Note: Pf denotes the producer price

Table 8 shows that a 1% increase in South Sumatra's producer price in the current month is associated with an approximately 0.073% increase in Jambi's wholesale price in the same month. The short-run elasticity is smaller than the long-run elasticity, indicating gradual price transmission. Inventories, purchasing schedules, and adjustment costs can delay responses across marketing levels (von Cramon-Taubadel & Goodwin, 2021), and Emediegwu and Rogna (2024) report comparable gradual adjustment in agricultural commodity markets.

The ECT in Table 8 is negative but statistically insignificant. Jambi's wholesale price is therefore not shown to adjust to deviations from its long-run relationship with South Sumatra's producer price. The analysis does not determine whether adjustment occurs through the producer price or through mechanisms outside the model.

Table 6 provides indicative evidence of a long-run equilibrium relationship between Jambi's wholesale and consumer prices. The downstream relationship is specified in Equation (10), and the residual is used as the ECT in the ECM reported in Table 9.

$$LPc\_Jambi_t = 1.417969 + 0.857179\ LPw\_Jambi_t \quad (10)$$

The coefficient of 0.857179 in Equation (10) indicates that a 1% increase in Jambi's wholesale price is associated with an approximately 0.857% increase in its consumer price in the long run. The Wald test rejects one-to-one transmission. Vavra and Goodwin (2005) explain that deviations from unity may reflect retailing costs, inventory management, and margin adjustment; the coefficient therefore cannot, by itself, establish market inefficiency.

The ECM estimates the contemporaneous response of consumer prices to changes in wholesale prices and the adjustment towards long-run equilibrium. The results are reported in Equation (11) and Table 9.

$$\Delta LPc\_Jambi_t = 0.001609 + 0.582625\Delta LPw\_Jambi_t - 0.197462ECT_{t-1} \tag{11}$$

Table 9. ECM Estimates for Jambi Wholesale and Consumer Prices

Variable	Coefficient	HC1 Standard Error	t Statistic	p-Value	Decision
C	0.001609	0.000507	3.172414	0.0024	Significant at the 1% level
D(LPw Jambi)	0.582625	0.076900	7.576421	0.0000	Significant at the 1% level
ECT(-1)	-0.197462	0.071068	-2.778501	0.0073	Significant at the 1% level

Source: Data Processed, 2026
Note: Pw denotes the wholesale price

Table 9 shows that a 1% increase in the wholesale price in the current month is associated with an approximately 0.583% increase in the consumer price in the same month. The ECT of −0.197462 indicates that approximately 19.75% of the previous month's disequilibrium is corrected through the monthly change in the consumer price. von Cramon-Taubadel and Goodwin (2021) emphasise that the ECT measures the speed of adjustment towards long-run equilibrium, not overall market efficiency. This finding is consistent with Deb et al. (2020) and Shaffitri et al. (2024), who identify wholesale markets as an important link between upstream and consumer markets.

Table 6 also shows that South Sumatra's producer price and Jambi's consumer price share a long-run equilibrium relationship at the 5% significance level. This relationship measures overall price transmission from producer to consumer through the intervening marketing stages; it does not imply a direct physical transaction between producers and consumers. The long-run relationship is specified in Equation (12).

$$LPc\_Jambi_t = 4.776428 + 0.518217\ LPf\_Sumsel_t \tag{12}$$

The coefficient of 0.518217 in Equation (12) indicates that a 1% increase in South Sumatra's producer price is associated with an approximately 0.518% increase in Jambi's consumer price in the long run. The coefficient is lower than the *Pf–Pw* and *Pw–Pc* elasticities, indicating that price transmission is attenuated across successive marketing functions. Shaffitri et al. (2024), Novianti et al. (2020), and Arida et al. (2023) likewise show that producer–consumer relationships do not necessarily yield proportional or symmetric transmission.

The final ECM estimates the contemporaneous response of Jambi's consumer price to changes in South Sumatra's producer price. A dummy variable controls the pronounced movement in March 2024 so that it does not dominate the estimated relationship. The results are reported in Equation (13) and Table 10.

$$\Delta LPc\_Jambi_t = 0.003469 + 0.053313\Delta LPf\_Sumsel_t - 0.021897ECT_{t-1} + 0.036333D_{2024}M_{03} \tag{13}$$

Table 10. ECM Estimates for South Sumatra Producer Prices and Jambi Consumer Prices

Variable	Coefficient	Standard Error	t Statistic	p-Value	Decision
C	0.003469	0.000923	3.760524	0.0004	Significant at the 1% level
D(LPF Sumsel)	0.053313	0.019634	2.715290	0.0087	Significant at the 1% level
ECT(-1)	-0.021897	0.023825	-0.919053	0.3618	Not significant
Dummy 2024M03	0.036333	0.007609	4.775054	0.0000	Significant at the 1% level

Source: Data Processed, 2026
Note: Pf denotes the producer price

Table 10 reports a positive but relatively small short-run elasticity, while the ECT is statistically insignificant. A 1% increase in South Sumatra's producer price in the current month is associated with an approximately 0.053% increase in Jambi's consumer price in the same month. The consumer price is not shown to adjust directly to deviations from its long-run relationship with South Sumatra's producer price. In contrast, Table 9 indicates that consumer-price adjustment occurs in relation to the wholesale price. This pattern is consistent with vertical-transmission theory, which places marketing institutions and wholesale markets between producer and consumer prices (Vavra & Goodwin, 2005; Deb et al., 2020).

Table 11. Price-Transmission Elasticities in the South Sumatra Chain

Relationship	Short-Run Elasticity	Long-Run Elasticity	ECT	Test of β = 1
Pf Sumsel → Pw Jambi	0.072523	0.600777	-0.009291; not significant	H_0 rejected
Pw Jambi → Pc Jambi	0.582625	0.857179	-0.197462; significant at the 1% level	H_0 rejected
Pf Sumsel → Pc Jambi	0.053313	0.518217	-0.021897; not significant	H_0 rejected

Source: Data Processed, 2026

Note: Pf denotes the producer price; Pw denotes the wholesale price; and Pc denotes the consumer price.

Table 11 shows that the South Sumatra chain has the broadest set of long-run relationships among the three chains because cointegration is identified for *Pf–Pw* and *Pf–Pc*. Nevertheless, a statistically significant equilibrium-correction mechanism is identified only for *Pw–Pc*. All long-run elasticities are below one and statistically different from one; market integration therefore does not imply proportional price transmission. von Cramon-Taubadel and Goodwin (2021) distinguish cointegration, which captures price linkage, from elasticity, which measures the magnitude of transmission; an assessment of efficiency additionally requires information on costs, margins, and market structure.

The internal consistency of the chain is reflected in the product of the *Pf–Pw* and *Pw–Pc* elasticities, which is close to the *Pf–Pc* elasticity. This proximity supports an interpretation of sequential transmission through the wholesale market, but it is not treated as a separately tested mathematical identity. Nasir et al. (2025) show that rice-marketing channels in Banyuasin involve assemblers, wholesalers, and retailers; Oksalia et al. (2023) identify differences in structure and performance across channels; and Wahyuni et al. (2023) show that marketing functions and channels generate heterogeneous costs and margins. These findings reinforce the need to interpret elasticities in relation to the functions performed by marketing institutions.

The results in Table 11 complement Shaffitri et al. (2024), who identify vertical integration at the national level, and Zahra et al. (2026), who document seasonal variation in transmission across producer, wholesale, and traditional-market prices. By retaining the geographical origin of the producer-price series, the present analysis shows that aggregate national conclusions cannot be applied uniformly to each regional chain.

Vertical Integration in the Local Jambi Chain

Table 12 shows that Jambi's local producer price is not cointegrated with either the wholesale or consumer price in Jambi. In spatial and vertical integration theory, geographical proximity reduces some transport costs but does not eliminate processing and storage costs, risk, quality differences, or information-search costs (Fackler & Goodwin, 2001). Administrative proximity is therefore insufficient to ensure a common long-run price equilibrium when downstream prices are formed from a mixture of supply origins and product specifications (von Cramon-Taubadel & Goodwin, 2021).

Table 12. Vertical Integration in the Local Jambi Chain

Relationship	Cointegration	Short-Run Response/ECT	Interpretation
Pf Jambi → Pw Jambi	Not cointegrated	ECM not estimated	The local producer price is not a long-run reference for the wholesale price
Pw Jambi → Pc Jambi	Indicative evidence of cointegration	Short-run elasticity 0.582625; ECT −0.197462, significant at the 1% level	Consumer prices adjust to changes in wholesale prices
Pf Jambi → Pc Jambi	Not cointegrated	ECM not estimated	No long-run producer–consumer relationship along the chain

Source: Data Processed, 2026

Note: Pf denotes the producer price; Pw denotes the wholesale price; and Pc denotes the consumer price

The *Pw Jambi–Pc Jambi* segment in Table 12 provides the same indicative evidence of cointegration because the wholesale and consumer price series are identical to those used in the other chains. The result describes integration in Jambi's downstream market rather than a specific contribution from locally produced rice. Deb et al. (2020) show that wholesale markets aggregate supply and demand information from multiple sources; a wholesale–consumer price relationship can therefore coexist with a lack of integration between the local producer price and downstream prices.

The *Pf Jambi–Pc Jambi* relationship measures overall producer–consumer price transmission along the marketing chain rather than a direct physical transaction. The absence of cointegration indicates that Jambi's consumer price does not share a stable long-run equilibrium with the local producer price. Price data alone are insufficient to evaluate effects on farmers' welfare because farm income also depends on sales volume, quality, production costs, and the producer's share of the final price. Oksalia et al. (2023) and Nasir et al. (2025) show that marketing-channel structure and margin distribution must be examined when linking prices to producer welfare.

Overall, vertical rice-market integration in Jambi differs by the geographical origin of the producer-price series and by marketing level. The South Sumatra chain has the broadest set of long-run relationships because its producer price is cointegrated with Jambi's wholesale and consumer prices, although transmission is less than proportional and a statistically significant equilibrium-correction mechanism is identified only in the wholesale–consumer segment. In contrast, the West Sumatra and local Jambi chains show no long-run relationship between producer and downstream prices, while the wholesale–consumer segment remains the most consistent channel of price transmission and adjustment. These results confirm that vertical integration is a property of a particular price pair and cannot be generalised to an entire marketing chain (von Cramon-Taubadel & Goodwin, 2021; Deb et al., 2020).

CONCLUSION

Rice prices at all marketing levels generally increased between January 2021 and April 2026, but their patterns differed across regions and marketing levels. West Sumatra's producer price was relatively higher for most of the period, South Sumatra's producer price displayed the strongest fluctuations, and Jambi's producer price rose more markedly from 2023 onwards. Jambi's wholesale and consumer prices adjusted more gradually and remained at higher levels towards the end of the period.

Rice market integration in Jambi Province varies across regions, marketing levels, and time horizons. Horizontally, the three producer markets do not share a long-run equilibrium. Short-run predictive linkages run from West Sumatra to Jambi and from Jambi to South Sumatra; these relationships do not represent physical trade routes or structural causality.

Vertically, the South Sumatra chain exhibits the strongest linkage because its producer price has long-run relationships with Jambi's wholesale and consumer prices, although transmission is less than proportional. The West Sumatra and local Jambi chains show no long-run relationship in the producer–wholesale or producer–consumer segments. The wholesale–consumer segment is the most consistent component of the chain in transmitting price changes and restoring equilibrium.

Price-stabilisation policy should account for differences in supply origin, marketing level, and the time horizon of price relationships. Price monitoring should be complemented by information on stocks, quality, supply origin, distribution costs, and marketing margins. Strengthening storage facilities, access to price information, quality standardisation, and local producer-marketing institutions should also be considered to improve market connectivity and producers' bargaining position.

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